

AD-A186 773

VISION ALGORITHMS AND PSYCHOPHYSICS(U) MASSACHUSETTS
INST OF TECH CAMBRIDGE W RICHARDS 02 OCT 87
AFOSR-TR-87-1534 \$AFOSR-86-0139

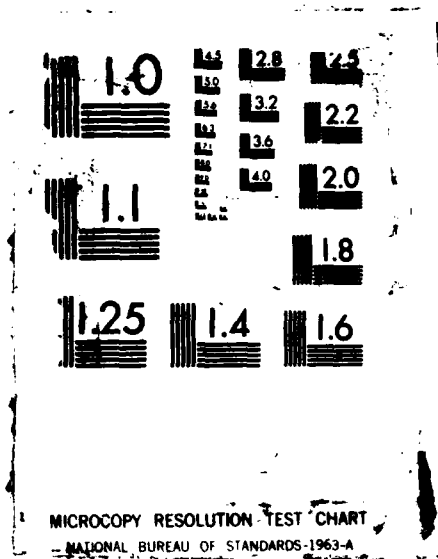
1/1

UNCLASSIFIED

F/G 12/1

NL





UNCLASSIFIED
SECURITY CLASSIFICATION

UT

1a REPORT SECURITY CLASSIFICATION
UNCLASSIFIED
2a SECURITY CLASSIFICATION

AD-A186 773

MENTATION PAGE

1b RESTRICTIVE MARKINGS

3 DISTRIBUTION/AVAILABILITY OF REPORT

Approved for public release; distribution unlimited.

2b DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)

AFOSR-TM- 87-1534

6a. NAME OF PERFORMING ORGANIZATION
MIT6b OFFICE SYMBOL
(If applicable)
E10-120

7a. NAME OF MONITORING ORGANIZATION

Air Force Office of Scientific Research/NL

6c. ADDRESS (City, State, and ZIP Code)

79 ANHEIST ST
CAMBRIDGE MA 02139

7b. ADDRESS (City, State, and ZIP Code)

Building 410
Bolling AFB, DC 20332-64488a. NAME OF FUNDING/SPONSORING ORGANIZATION
AFOSR8b. OFFICE SYMBOL
(If applicable)
NL

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

AFOSR-86-0139

8c. ADDRESS (City, State, and ZIP Code)

Building 410
Bolling AFB, DC 20332-6448

10. SOURCE OF FUNDING NUMBERS

PROGRAM
ELEMENT NO.
61102FPROJECT
NO.
2313TASK
NO.
A5WORK UNIT
ACCESSION NO

11. TITLE (Include Security Classification)

(U) VISION ALGORITHMS AND PSYCHOPHYSICS

12. PERSONAL AUTHOR(S)

DR. WHITMAN RICHARDS

13a. TYPE OF REPORT
ANNUAL13b. TIME COVERED
FROM 1 APR 86 TO 31 MAR 8714. DATE OF REPORT (Year, Month, Day)
87100215. PAGE COUNT
5

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

HUMAN VISION ; PSYCHOPHYSICS

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Over the past year, we have made significant progress in understanding shape perception based on curvature extrema. Through psychophysical experiments in conjunction with H.R. Wilson (Univ. of Chicago), we now are able to identify which of several computer algorithms for extracting curvature are biologically the most feasible.

DTIC
ELECTE
OCT 27 1987
S D

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT

☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL

DR JOHN F. TARBNEY

22b. TELEPHONE (Include Area Code)

(202) 767-5021

22c. OFFICE SYMBOL

NL

**Vision Algorithms and Psychophysics
(Annual Technical Report, August 1987)**

To: Dr. John Tangney, AFOSR 86-0139
From: Whitman Richards
MIT E10-120 617-253-5776
79 Amherst St. Cambridge, Mass. 02139

I. Summary

Over the past year, we have made significant progress in understanding shape perception based on curvature extrema. Through psychophysical experiments in conjunction with H.R. Wilson (Univ. of Chicago), we now are able to identify which of several computer algorithms for extracting curvature are biologically the most feasible.

II. Theoretical Studies

Our work has stressed the recovery of 3D shape from 2D image contours, such as a silhouette or cartoon. The description of the 3D shape we desire is topological rather than metrical. Hence our representation for 3D shape has been Gaussian curvature, where the object is described in terms of its "bumps" and "dents", or "ridges" and "furrows". We have shown how such a description can be recovered from the occluding image contour (Richards, Koenderink & Hoffman, 1987). This work continues in two directions: (1) inferring 3D shape in the presence of occlusions (with Koenderink), and (2) viewing shapes in terms of the way they were created—i.e. a process or developmental approach (Leyton, 1987).

In order to make inferences about 3D shape from 2D image contours, it is necessary to have an explicit description of the image contour itself. Over the past few years, we have argued for a curvature-based description, because such image features indicate directly the part boundaries of a 3D object, and also are efficient features for capturing the general topology of any part (Hoffman & Richards, 1986). However, computing curvature from image contours is non-trivial. At least two numerical derivatives must be taken. How should this be done and what space constraints should be used? Recently, we have presented two theoretical schemes for calculating curvature in a biological system (Koenderink & Richards, 1987). Both relate to existing computer vision algorithms (Parent & Zucker, 1986; Richards et al., 1986).

Recent psychophysics (to be described briefly below) suggests both schemes are used by the human visual system, but over different ranges of curvature.

III. Algorithms

At present, most computer implementations for extracting descriptions of 2D shapes from images use serial algorithms. An edge list for a curve is created, and this list is then twice differentiated using some (rather arbitrary) space constant. Often we simply choose a space constant which is a certain percent of the length of the list. However, a more powerful approach is to vary the space constant used for differentiating the curve, and then to compare locations of curvature extrema across scales (Richards et al., 1986). This procedure yields curvature extrema both for the textural aspects of silhouette as well as extrema for the parts of the shape—its bump and dents. Our algorithm is fairly powerful, delivering a description of the curve in terms of a string of "codons". Such strings are quite robust to projective distortions in the shape, or slight changes in view. On complex natural images, results are promising. Changing the viewpoint of the scene, or moving a shape (such as an animal) still results in similar codon descriptions for the object.

We have also used the codon string as a basis for stereopsis. Here enormous distortions between the two image pairs are now possible without failure of proper correspondence. This scheme eliminates the need for an epipolar constraint, and can be applied to heavily aliased pictures or shapes.

IV. Psychophysics (with H.R. Wilson)

As mentioned above, our computer algorithm for extracting curvature for shape descriptors examines a contour at several scales. This is expensive, but required theoretically if one wishes an entirely unambiguous description of a curve. Surprisingly, we have found that the human visual system computes curvature only at the finest scale available. This result is in sharp contrast to the coarse-to-fine strategies used in most vision algorithms, such as stereo and motion (Richards & Wilson, 1987).

Our second psychophysical result is that the human visual system uses two different schemes for computing curvature, one for high curvature, and a separate method for low (Wilson & Richards, 1987). For high curvatures, a "local" method is used which is equivalent to our computer algorithm in the limit as the curve segment approaches zero. For low curvatures, a comparison is needed between two regions along the curve—something like a symmetric axis computation where segments are compared for co-circularity (Parent &



For	
CRA&I	<input checked="" type="checkbox"/>
TAB	<input type="checkbox"/>
Index	<input type="checkbox"/>
Availability Codes	
Dist	Avail and/or Special
A-1	

Zucker, 1986). Both schemes have been analysed theoretically by Koenderink & Richards (1987).

V. Citations

Books:

Ullman, S. & Richards, W., eds. (1984) *Image Understanding 1984*. Norwood, NJ: Ablex.

Richards, W. & Ullman, S., eds. (1987) *Image Understanding 1985-1986*. Norwood, NJ: Ablex.

Richards, W. (1988) *Selections in Natural Computation*. Cambridge, MA: MIT Press. In preparation.

Book chapters:

See contents of *Selections in Natural Computation*.

Papers:

Bobick, A. & Richards, W. (1986) Classifying objects from visual information. *MIT AI Memo 879*.

Richards, W. & Bobick, A. (1987) Playing 20 Questions with nature. In *Computational Processes in Human Vision*. Z. Pylyshyn (ed.); Norwood, NJ: Ablex.

Dawson, B. & Treese, G. (1985) Locating objects in a complex image. *SPIE Architecture & Algorithms for Digital Image Processing II*, 534:185-192.

Dawson, B. & Treese, G. (1984) Computing curvature from images. *SPIE Architecture & Algorithms for Digital Image Processing II*, 504:175-182.

Hoffman, D.D. & Richards, W. (1984) Parts of recognition. *Cognition*, 18:65-96.

Koenderink, J.J. & Richards, W. (1988) Two dimensional curvature operators. Submitted to *Jrl. Opt. Soc. Am. A*.

Leyton, M. (1987) A process grammar for shape. *AAAI*, in press.

Leyton, M. (1987) Process recovery. Submitted to *Proc. Int. Jnt. Conf. Artif. Intell.*

Leyton, M. (1987) Symmetry-curvature duality. *Computer Vision, Graphics & Image Processing*, 38:327-341.

- Richards, W. (1985) Structure from stereo and motion. *Jrl. Opt. Soc. Am. A*, 2:343-349.
- Richards, W., Dawson, B. & Whittington, D. (1986) Encoding contour shape by curvature extrema. *Jrl. Opt. Soc. Am. A*, 3:1483-1491.
- Richards, W. & Hoffman, D.D. (1985) Codon constraints on closed 2D shapes. *Computer Vision, Graphics & Image Processing*, 31(3):265-281.
- Richards, W., Koenderink, J.J. & Hoffman, D.D. (1985) Inferring 3D shapes from 2D silhouettes. *Jrl. Opt. Soc. Am. A*, 4:1168-1175; and *MIT AI Memo 840*.
- Richards, W. & Lieberman, H. (1985) Correlation between stereo ability and the recovery of structure from motion. *Amer. J. Optom. Physiol. Optics*, 62:111-118.
- Rubin, J. & Richards, W. (1984) Color vision: representing material categories. *MIT AI Memo 764*; also chapter 4 in *Image Understanding 1985-1986*, Richards, W. & Ullman, S. (eds.) Norwood, NJ: Ablex, 1987.
- Truvè, S. & Richards, W. (1986) From Waltz to Winston (via the Connection Table). In *Selections in Natural Computation*, W. Richards, in press; also in *Proc. Inst. Conf. on Computer Vision*, London, 1987.

Presentations:

CIAR-UWO Workshop on Vision, London, Ontario, April 1986

Richards, W. What is a feature?

Ullman, S. Visual routines, basic operations, and image chunking.

Optical Society of America, Annual Meeting, San Diego, October 1984

Bobick, A. using mirror reflections to recover shape. *Jrl. Opt. Soc. Am. A*, 1(12):1253A.

Hoffman, D.D. & Richards, W. Parts of recognition. *Jrl. Opt. Soc. Am. A*, 1(12):1215A.

Rubin, J. Telling actors from objects with visual motion. *Jrl. Opt. Soc. Am. A*, 1(12):1266A.

Optical Society of America, Annual Meeting, Washington, DC, 1985

Bobick, A. Discriminating features and information theory. *Jrl. Opt. Soc. Am. A*, 2(13):P16A.

Richards, W. & Hoffman, D.D. Inferring 3D shapes from 2D codons. *Jrl. Opt. Soc. Am. A*, 2(13):P51A.

Saund, E. Representation using scale space. *Jrl. Opt. Soc. Am. A*, 2(13):P19A.

Optical Society of America, Annual Meeting, Rochester, NY, 1987

Wilson, H.R. & Richards, W. Mechanics of curvature discrimination. *Jrl. Opt. Soc. Am. A*, 13(9):P97A.

Richards, W. & Wilson, H.R. Comparison between computer and biological algorithms for extracting curvature. *Jrl. Opt. Soc. Am. A*, 13(9):P97A.

END
DATE
FILMED
JAN
1988